Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance

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Abstract

This paper examines configurations of carbon neutrality in the building and energy sector as expressed in the urban governance documents of the members of the Carbon Neutral Cities Alliance (CNCA). 'Carbon neutrality' is a mutable idea, which makes it unclear what kinds of future urban systems are imagined. As self-identified pioneers of deep decarbonization, the CNCA members are constructing ideas about what carbon neutral means and how urban systems should be changed to reduce greenhouse gas emissions. In this paper, climate governance policy documents provide a window to understand how these carbon neutral imaginaries are being constructed. The analysis draws on discourse analysis and textual network analysis to unpack the sociotechnical configurations that are planned to be mobilized to constitute carbon neutral built environments. Concept map visualizations are used to scrutinize planned configurations of objects (e.g. solar photovoltaics, district energy, and energy efficiency technology) and policy instruments (e.g. energy use benchmarking and urban planning tools). The analysis shows three key building and energy configurations: 1) The District Energy City, 2) The Zero Net Energy City, and 3) The Natural Gas Transition City. Furthermore, the findings demonstrate that urban imaginaries of carbon neutrality are incorporating complex configurations of sociotechnical objects while, at the same time, distinct sociotechnical configurations are being favoured in individual places. These configurations inform sociotechnical imaginaries that will continue to drive policy outcomes over time.

Keywords: carbon neutral; governance; cities; climate change; mitigation

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Introduction

"Avoiding the most destructive effects of climate change requires *reimagining and reinventing* our great urban centers…to put them on a path toward a zero-carbon future." (Carbon Neutral Cities Alliance, 2015, emphasis added)

Addressing the climate change crisis requires transformative change. In light of this, some local governments have started to take what they describe as a transformative rather than incremental approach to greenhouse gas emission reduction (Carbon Neutral Cities Alliance, 2015). They are trying to chart the waters of urban "deep decarbonization" (Carbon Neutral Cities Alliance, 2015). However, there are no models for urban systems that have overcome fundamental fossil fuel dependence and become carbon neutral. In fact, there is no single fix that can overcome widespread carbon lock-in across society (Unruh, 2000). The governance of transformation instead requires normative steering and negotiation about what the future ought to be (Meadowcroft, 2009). So what is the future carbon neutral city actually imagined to be?

The urban is an increasingly important wedge of climate governance (Castán Broto & Bulkeley, 2013; Bulkeley & Betsill, 2013; Reckien et al., 2014; Romero-Lankao, 2012) . We know that actors from across government, private, and community spheres are intervening in social and technical urban systems to try to address climate change (Bulkeley & Castán Broto, 2013). However, we also know that these efforts have encountered barriers and have often failed to address key drivers of climate change (Bulkeley & Betsill, 2013; Burch, 2010; Romero-Lankao, 2012). Thorny barriers are no surprise since carbon lock-in creates a policy inertia that makes it difficult to make systemic change (Unruh, 2000). Despite these setbacks, urban policy makers have started to explicitly target wide-reaching transformations, which is beyond the scope of action previously studied by scholars. This paper focuses on this unique slice of urban carbon governance where actors are deliberately reaching for decarbonization. To understand how the decarbonized future of cities is being imagined, we unpack the low carbon futures discursively constructed by urban actors in the cities that are members of a transnational network called the Carbon Neutral Cities Alliance.

Transnational climate governance networks, such as the Carbon Neutral Cities Alliance, are intertwined with visions of scientific and technological progress (sociotechnical imaginaries), which carry with them implicit ideas about public purposes, collective futures, and the common good. Yet, because policies are determined by local sociotechnical conditions, sociotechnical imaginaries vary across sites. In principle, imagined futures—or the balance between their sociotechnical configurations—could be different. We use this understanding of imaginaries in our examination of policy documents aimed at achieving carbon neutrality. The imaginary of urban carbon

neutrality is transnationally linked through the network, but this study focuses on the climate governance documents of the member cities rather than the transnational network. More specifically, we unpack the underlying discourses in member cities' climate governance documents in order to delve deeper into imaginaries of urban carbon neutrality. We argue that science and technology studies scholars' work on sociotechnical configurations is helpful to structure this unpacking. It is important to note that, although low carbon transitions must take place across urban systems and must be integrated with adaptation to climate change, this study focuses specifically on efforts to reduce greenhouse gas emissions in the buildings and energy sector in order to maintain a manageable scope. This focus is justified since building oriented initiatives make up a substantial proportion of urban carbon governance (C40 Cities & ARUP, 2014; Castán Broto & Bulkeley, 2013).

Based on our analysis, we interpret three key building and energy configurations: 1) The District Energy City, 2) The Zero Net Energy City, and 3) The Natural Gas Transition City. Furthermore, we find that, despite the importance of a few policy instruments and objects, urban imaginaries of carbon neutrality are incorporating complex configurations of sociotechnical objects. At the same time, distinct sociotechnical configurations are being favoured in individual places. These configurations are important because they feed into sociotechnical imaginaries that drive policy outcomes and influence the shape of urban space.

We begin by explaining how literature on imaginaries helps us to consider the construction of the future and by elaborating on our use of configurations literature to unpack imaginaries. In the findings section, we first present textual network analysis visualizations and explain how we used this approach to unpack sociotechnical patterns. We then analytically distinguish three descriptive configurations of future carbon neutral cities based on patterns in the studied documents. In doing so, this paper contributes to literature on the production of meaning and power in the negotiation of environmental governance while expanding the urban carbon governance literature to include the ontological politics of carbon neutrality.

Governing the Future with Imaginaries

There are many different ways to construct the future. In planning literature, scholars write about scenarios, roadmaps, benchmarking, or visioning exercises, which are all tools used in various ways to imagine the future of urban areas (for example Boyko et al., 2012 and Shaw et al., 2009). Political scientists have written extensively about utopian thinking (Goodwin & Taylor, 2009) and scenario analysis (Garb, Pulver, & Vandeveer, 2008). Other scholars have used the idea of imaginaries to discuss the ways

that ideas about desirable and attainable futures are constructed through the lens of our understanding of society's relationship to science and technology and the constitution of state-citizen relations (Jasanoff & Kim, 2015). These literatures all recognize the different ways that we talk about what the future *ought* to be. However, we find imaginaries particularly helpful for our purposes because it provides a conceptual framework to understand feedback between talk and practice while also allowing for a dynamic and fluid consideration of the urban.

Particularly influential applications of the concept of imaginaries include Anderson's definition of a nation as "an imagined political community" (Anderson, 2006) where people maintain and reproduce the collective community through shared practices. Expanding on this, Taylor used social imaginary to refer to how people broadly understand their social existence and he explored how changing imaginaries contribute to patterns of historical change (Taylor, 2004). Imaginaries have also been conceptualized in the context of the urban. The concept of urban imaginaries recognizes that a collective imagination is developed and reinforced through the urban dwellers' daily practices, which builds the city as, at the same time, both an indefinite and a singular place (Çinar & Bender, 2007). Considering urban imaginaries can help us to understand the imagined political community of city, but it can also help us to examine how urban imaginaries from different places might transnationally influence one another (Hult, 2013). Imaginaries ontologically allow for flexible and fluid understandings of the urban by orienting aspirations, socio-material conditions and political processes towards the performance of alternative urban configurations.

However, Jasanoff and Kim (2015) point out the lack of attention paid to science and technology in much of the work on imaginaries. To fill this lacuna, they propose the concept sociotechnical imaginaries. Sociotechnical imaginaries are defined as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff & Kim, 2015). They argue that imaginaries "at once describe attainable futures and prescribe futures that states believe ought to be attained" (Jasanoff & Kim, 2009). Though much of the application of the sociotechnical imaginaries concept to-date has focused on nation-states, it can be applied to any organized groups and therefore is applicable to the urban (Jasanoff & Kim, 2015).

As the work of these scholars has shown, imaginaries are important because they influence possible future trajectories of the city through their repeated performance. The performative nature of imaginaries echoes the assertion of discourse scholars that language does political work that paves the way for different kinds of policy outcomes

(Hajer & Versteeg, 2005). The notion of sociotechnical imaginaries reaches beyond language, to the materiality of political action. 'Talk' is intrinsically connected to the organization of sociotechnical governance arrangements. In this way, talk about carbon neutral governance and the objects that are enlisted in carbon transitions constrain some futures while enabling others.

Furthermore, the concept of urban imaginaries is used in this paper to engage with the spatially nebulous concept of 'the city'. Urban scholars have called for attention to the ways that urban systems can be understood as processes of metabolism and flow rather than a fixed, bounded space (Gandy, 2004). Recently, these calls have focused on the importance of considering the relationship between the 'city' and the 'hinterland' when studying the urban (Huber, 2015) and the global reach of urbanization as a process (Angelo & Wachsmuth, 2014). In other words, we should not cut off the far-reaching tendrils of urban systems in misguided efforts for analytical simplicity. Embracing fluidity is similarly key to recent understandings of climate governance. Here, the idea of discrete levels of the international, national and local has given way to consideration of "the emergence of new political spaces" (Bulkeley & Betsill, 2013) that tackle climate governance across these boundaries. An imaginaries framework accommodates these calls for dynamic understandings of the urban and of climate governance since it focuses on the ways that social and material reality is understood and performed, as well as how that understanding influences the future, without prescribing the scope and the participants. These features make imaginaries suited for the consideration of the wide range of authority and broad breadth of spatial scope of urban climate governance policy documents. In particular, the concept of imaginaries can encompass a broad scope while still connecting with the idea of a particular urban place.

Our purpose is to understand and compare imaginaries of urban carbon neutrality. To do so, we unpacked the underlying discourses represented in climate governance documents using configurations literature, which draws from science and technology studies. Science and technology studies sees technologies as embedded elements in sociotechnical systems so that the social and the technical are co-constitutive (Bijker & Law, 1992; Coutard, 1999). Central concerns in this body of literature are often the relationships between objects and actors (Marres, 2012) and the ways that co-dependent technological objects and social organization are configured into sociotechnical orders (Walker & Cass, 2007). This body of work is relevant for this paper since it has tackled the materiality of networks and has wrestled with similar questions on the radical transformation of infrastructure. This approach also fosters an emphasis on objects, which is usually underemphasized in work on imaginaries. In one study with an aim similar to ours, Walker and Cass (2007) analyze the relationships between technological objects and forms of social organization related to renewable energy policy in the UK.

They identify five different configurations of renewable energy implementation by parsing out underlying discourses, participating technologies, size of projects, and characteristics of social and infrastructural organization (Walker & Cass, 2007). As a concept, configuration is focused on the organizing or ordering of sociotechnical objects – the ways they are brought together, sorted, held together, and/or drawn apart. Sociotechnical imaginaries, on the other hand, are broader visions of desirable futures that are collectively held and publically performed. We argue that a configurations approach offers a thorough framework to unpack imaginaries by breaking them down into constitutive sociotechnical configurations.

Methods

This study focuses on a sample of the climate governance policy documents produced on behalf of the 17 cities that are founding members of the Carbon Neutral Cities Alliance (CNCA). The CNCA was officially founded in 2015 and is administered by the Urban Sustainability Director's Network with the C40 Cities Climate Leadership Group and the Innovation Network for Communities (USDN, 2015). The local governments that are founding members of the CNCA are listed in Table 1. The members of the CNCA have "aggressive long-term carbon reduction goals" (USDN, 2015) and participate in the network to share lessons on planning and implementation of decarbonization practices (USDN, 2015). The sample was limited to policy documents of CNCA founding members; this scope is justified because CNCA founding members are among the first local governments trying to intentionally achieve carbon neutrality and the stated goal of the transnational network is to inspire similar action in other cities outside of the network. As a result, the visions of future carbon neutral cities developed by urban actors for these cities are particularly influential and may define what counts as urban decarbonization.

Table 1 Members of the Carbon Neutral Cities Alliance and the studied sample of climate governance policy documents

City	Documents Included in Analysis
Berlin, Germany	Climate-Neutrality Berlin 2050: Results of a Feasibility Study
Boston MA, USA	Greenovate Boston: 2014 Climate Action Plan Update
Boulder CO, USA	Boulder's Climate Commitment 2015
Copenhagen, Denmark	CPH 2025 Climate Plan; Copenhagen Energy Vision 2050
London, United Kingdom	Delivering London's Energy Future; The Mayor's Climate Change and Energy Strategy (2011)
Melbourne, Australia	Melbourne - Zero Net Emissions 2020
Minneapolis MN, USA	Minneapolis Climate Action Plan 2013
New York NY, USA	New York City's Pathways to Deep Carbon Reductions; OneCity Built to Last

Oslo, Norway	Oslo Green Capital Brochure; Urban ecology programme 2011 - 2026
Portland OR, USA	Climate Action Plan 2015
San Francisco CA, USA	San Francisco Climate Action Strategy 2013 Update
Seattle WA, USA	Getting to Zero: A Pathway to a Carbon Neutral Seattle (2011); Climate Action Plan (June 2013)
Stockholm, Sweden	Roadmap for a Fossil Fuel-Free Stockholm 2050
Sydney, Australia	City of Sydney Decentralized Energy Master Plan 2015-2030; City of Sydney Energy Efficiency Master Plan: Improving Energy Productivity 2015-2030
Vancouver, Canada	Greenest City: 2020 Action Plan; Renewable City Strategy 2015-2050
Washington DC, USA	Sustainable D.C.
Yokohama, Japan	FutureCity Initiative; Mid Term Plan of the City of Yokohama; Master plan of YCSP

For each of the seventeen founding members of the CNCA, we collected climate governance policy documents produced on behalf of each city with an emphasis on the most recent documents at the time of analysis (November 2015). This sample of policy documents (see Table 1) formed the body of text that was object of study for this research. It is vital to focus on these documents since the policy discourses on deep decarbonization are largely textual so far. Furthermore, these documents provide insight into developing sociotechnical imaginaries of urban carbon neutrality where, as we have argued, language does political work to drive material outcomes. The policy documents included in the sample span from 2009-2015 and range from short-term climate action plans to long term 'roadmaps' that set out carbon neutral scenarios in the distant future. The policy documents focus on carbon governance undertaken in the name of a place, but the documents often reference transnational flows and significantly include governance beyond local government regulatory power. The sample focuses on municipal-led documents, but these documents were often developed with the involvement of stakeholders like local businesses, community groups and local citizens. One purpose of these plans is to bring together urban actors on this issue and it is likely that the documents conceal struggle and contestation within the city. Future research could seek to understand alternative discourses of carbon governance within cities, but that is beyond the scope of this paper. All documents were available publicly on the Internet in English. Because the transnational network interaction is conducted largely in English, key climate governance documents were available in English for all seventeen cities.

We used textual network analysis as an interpretive tool to examine the discourses, material objects, and policy prescriptions in carbon neutral governance. By systematically extracting and analyzing the links between these socio-material objects in a body of texts (the sample listed in Table 1), we can draw a collective concept map of

how carbon neutrality is conceived among the members of the CNCA. Textual network analysis enables us to gain a better understanding of how ideas are connected across our sample of texts, augmenting our configurations analysis by highlighting the centrality, marginality and similarity of the connection between ideas, arguments or objects across a body of texts (Carley, 1993; Palmquist, Carley, & Dale, 1997). The measure of centrality is the number of links directed toward and going out from a particular concept. If a particular concept has a large number of links to other concepts, that is, greater centrality, it will have a greater importance within the concept map than a concept that is poorly linked. Here it is used as a tool to help interpret relationships between objects of carbon neutral governance and between policy instruments in the sample of climate governance documents. 'Objects of governance' means the urban elements that will be increased to achieve carbon neutrality (e.g. energy efficient technology). 'Policy instruments' refers to the means through which urban actors plan to bring about those increases (e.g. financial incentives).

It is important to note that although one might assume that some of the objects of governance and policy instruments are predominately material technologies (e.g. geothermal power) and others one might consider social (e.g. urban planning tools), they are better considered as sociotechnical. The mobilization of 'solar', for example, could require solar photovoltaic panels, wires, inverters, electricity, installation labour, financial inventive mechanisms, local government policies, a household rooftop etc. The labels that we have chosen in the analysis represent both the social and the technical aspects. Taking this into account, our textual network analysis unpacks urban imaginaries of carbon neutrality to show which sociotechnical objects will be mobilized and what kinds of connections exist between them.

Relevant objects of governance and policy instruments were identified using a grounded theory approach during qualitative analysis of the sample of climate governance texts. These objects appear as nodes in the network graphs. We built a two-mode matrix where the rows represented each city (n = 17) and the columns represented each identified object of governance (n = 16) and another two-mode matrix where the rows represented each city and the columns represented each identified policy instrument (n = 11). For each city, we coded for the presence or absence of each object and policy instrument (see Appendix 1). Presence was judged using a close reading of the documents by one of the authors rather than quantitative content analysis for the exact terms used here, and one small passing reference to an object or policy instrument was not counted as presence.

We then transformed these matrices into adjacency matrices, which are used to represent the co-occurrence of bits of text across a larger sample of text (Palmquist et al.,

1997). The adjacency matrices represented the number of times that objects (or instruments) co-occur within climate governance texts referring to one city. We entered the results into the network analysis software UCInet and used Netdraw to create visualizations (Borgatti, Everett, & Freeman, 2002). By focusing on co-occurrences, the resulting visualizations show the strength of connection (ties) between objects or instruments. This is a measure that allowed us to examine which strings of objects are dominant among the members of the CNCA and how the strength of ties between objects of governance reflect divisions or clusters across this body of texts. The centrality of different objects of governance can also be visualized by how often each object is connected to all other objects across our sample of texts, reflected by the size of nodes. The complexity and density of the concept map is indicated by the number of objects present and the extent to which each object is connected to all other themes. While there are many more network measures available to analysts (Scott, 1991), these were the most useful to address our research questions.

We also conducted a qualitative discourse analysis of the sample of texts. The discourse analysis had two purposes: 1) informing the identification of relevant objects of governance and policy instruments to feed into the textual network analysis, and 2) interpreting key sociotechnical configurations of urban carbon neutrality. The discourse analysis drew on the approaches of Hajer and Versteeg (2005) and Foucault (1972). One of the authors (author name) performed a close and reflective reading of the sample of texts listed in Table 1 (Genus & Theobald, 2016; Waitt, 2005) and employed the strategies distilled by Waitt (2005), who recommends identifying key themes through absorption in the texts and the investigation of the ways in which 'truth' is constructed, inconsistencies are developed, and silencing mechanisms are included. In addition to feeding into the textual network analysis, the discourse analysis allowed us to iteratively distill key sociotechnical configurations of urban carbon neutrality. These configurations are not explicitly given within the texts but, instead, are heuristic constructs we use to interpret how sociotechnical elements are being drawn together to tell stories about what future urban decarbonization might look like in particular places.

These methods allow us to examine the sociotechnical configurations that make up imaginaries of future carbon neutral cities in two ways. The textual network analysis acts as an interpretive tool that allows us to analyze what kinds of objects are imagined to be important components of future carbon neutral cities and what kinds of policy instruments will be used to achieve those futures. In this way, we unpack the sociotechnical components that make up planned carbon neutral governance. The discourse analysis allows us to also interpret patterns in the ways that discourses, material objects and policy instruments, which we analyze as sociotechnical objects rather than as objects from different ontological realms (e.g., the cognitive, the material, and the social),

are assembled in policy documents to consider emphases on particular kinds of sociotechnical configurations. Therefore, the analysis broadly identifies the sociotechnical objects that urban actors imagine will make up future carbon neutral cities on one hand, while, one the other, interpreting patterns in the imagined assemblage of those sociotechnical objects for particular places.

Findings: Unpacking Configurations of Urban Carbon Neutral Imaginaries

Which objects are targeted by urban carbon neutral governance?

Our purpose with the visualization in Figure 1 is to analyze which objects are dominant targets of carbon neutral governance across the Carbon Neutral Cities Alliance. You will recall that we derived the nodes by allowing them to arise through the discourse analysis, which means they reflect important patterns and silences within the texts. Ties between objects mean that they co-occur in the governance texts for a particular city. A heavier line weight means that the objects co-occur more frequently across the sample of texts. As a result, the most dominant (or frequently occurring) objects are shown at the confluence of the heaviest concentrations of line weights.

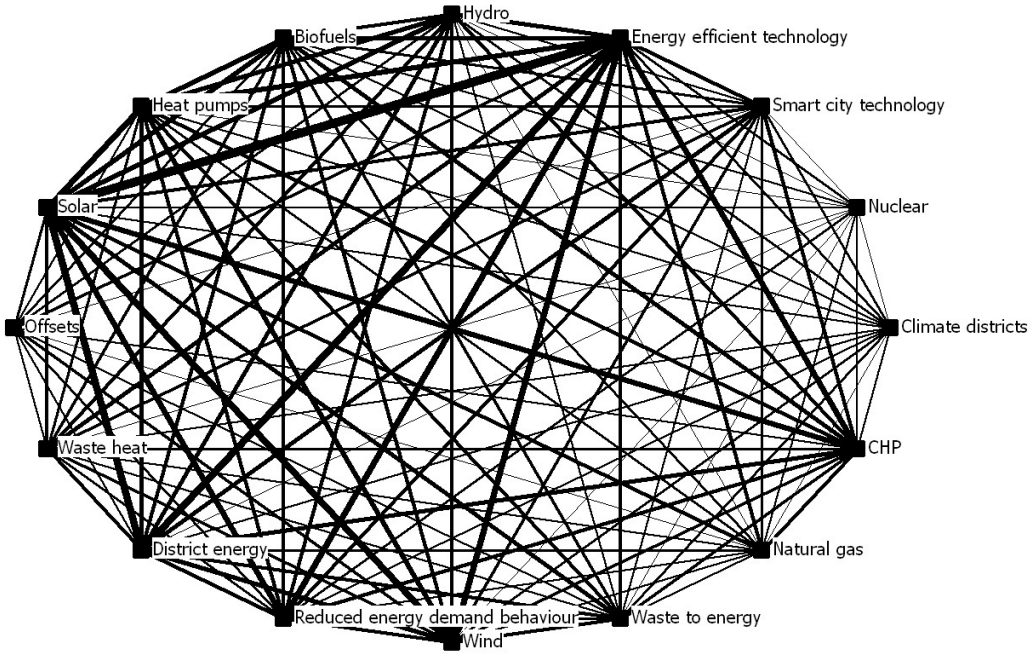

Figure 1 Visualization of the objects targeted in climate governance policy documents of the founding Carbon Neutral Cities Alliance members. The nodes represent the urban objects that will be increased to achieve carbon neutrality, where ties show that they co-occur in our sample of texts and the line weights show the relative frequency of co-occurrence.

Several interesting features can be interpreted from this visualization. The visualization shows that district energy, energy efficient technology, and solar power have particularly key roles in urban imaginaries about carbon neutral futures. Heat pumps (air and geothermal), combined heat and power (CHP), biofuels, wind power, and reduced energy demand behaviour also seem to play moderately important roles. Reduced energy demand behaviour has strong connections to energy efficient technology and solar, but otherwise is not a very dominant object of governance. Overall, the sample of policy documents emphasizes the technological aspects carbon governance. In addition, it would not be unreasonable for one to assume that fossil fuels would be replaced in urban futures that have achieved carbon neutrality. Nonetheless, natural gas is included in some futures. Natural gas has moderately strong connections to district energy and combined heat and power (CHP). We can see that there is high degree of connectivity across the objects, which shows that the seventeen cities are drawing on a fairly consistent suite of options—no object appears dominant in this concept map. This is as opposed to, for instance, divergent 'camps' favoring completely discrete options. The visualization also shows that carbon neutral governance is not planning a silver bullet, but instead reflects anticipated use of a complicated suite of sociotechnical tools. While configurations in particular places favour some sociotechnical objects over others, they still plan to draw on a broad suite of technologies and behaviours in some way. This suggests that urban imaginaries of carbon neutrality are incorporating complex configurations of sociotechnical objects. Again, the content of imaginaries is important because sociotechnical imaginaries are powerful drivers of policy outcomes that shape urban space (Jasanoff & Kim, 2015).

What kinds of policy instruments will be used to achieve carbon neutral futures?

Urban carbon neutral imaginaries enlist various policy tools as planned mechanisms to achieve low carbon urbanism. Figure 2 compares patterns of emphasis on particular policy instruments in the studied climate governance documents. We created labels for the policy instrument categories through the discourse analysis and these labels are explained in more detail in Table 2.

Table 2 Explanation of policy instrument categories

Benchmarking and Reporting	Mandatory energy use benchmarking and reporting of results for at least a portion of urban buildings
Building Standards	Requirements to meet a building standard with an energy or carbon element
Capacity Building	Provide information, increase skills, provide technical analysis
Financial Incentives	Provision of grants, loans and other financial rewards
Financial Penalties	Application of fees or taxes
Lead by Example	Activity targeting municipal operations or assets that demonstrates behaviour/technology to be imitated
Lobby Authorities	Target change in the policy of another level of government, business, or other agency beyond the direct control of the municipality
Municipal Energy Supplier	Deliver carbon and energy changes through a municipally controlled utility company
Private Sector Engagement	Engagement of the business sector through activities like awards for top 'green' businesses
Public Sector Engagement	Public displays related to energy and carbon, as well as continued engagement with citizens through committees and other groups
Urban Planning Tools	Use of planning tools like zoning and fee structures

Similar to Figure 1, ties between policy instruments mean that they co-occur in the governance texts for a particular city. A heavier line weight means that the instruments co-occur more frequently across the sample of texts. The most dominant (or frequently occurring) instruments are shown with the confluence of the heaviest concentrations of line weights. The visualization (see Figure 2) shows that capacity building, financial incentives, leading by example, building standards, and benchmarking and reporting are important policy instruments in carbon neutral governance. Interestingly, this represents a mix of enabling and regulatory tools. Financial penalties, on the other hand, are only weakly connected to other mechanisms. There is an emphasis on demonstration, information provision, and incentives. The policy instruments described often depend on the extension of municipal authority to influence other actors where regulatory control is not possible. Sociotechnical imaginaries delimit attainable and desirable futures (Jasanoff & Kim, 2015), but they also delineate the means through which that future will be achieved. This analysis suggests that urban carbon neutral imaginaries will be enacted

through the conscription of diverse public, private and individual authorities into a shared vision. Though regulatory governance is included, the policy tools largely emphasize 'carrot' over the 'stick' approaches to policy design. This may reflect the types of municipal power available and/or a partnership approach to private capital.

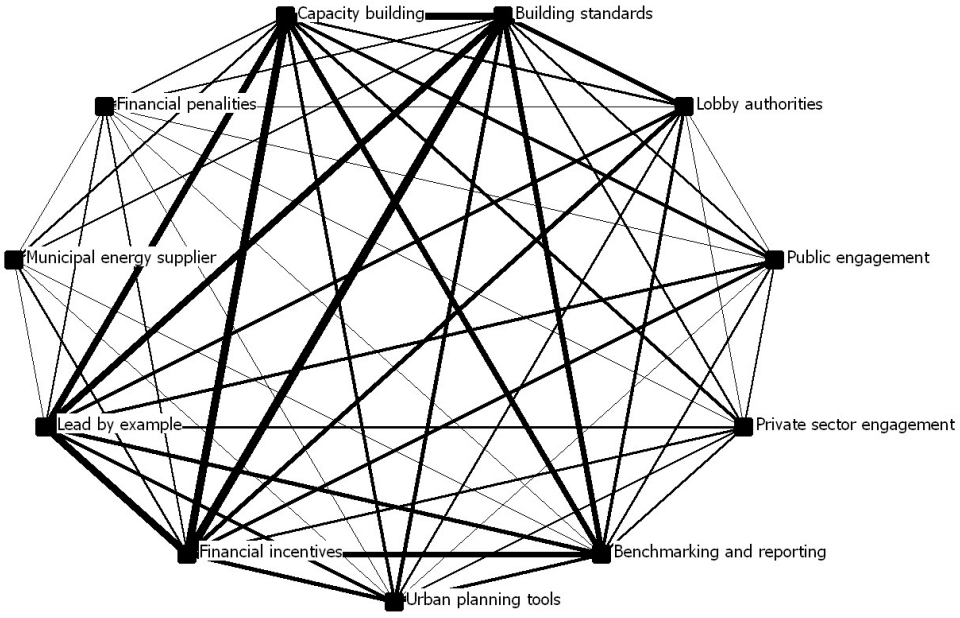

Figure 2 Visualization of the policy instruments emphasized in climate governance documents of the founding Carbon Neutral Cities Alliance members. The nodes represent the means through which urban actors plan to bring about increases in particular urban objects to achieve carbon neutrality, where ties show that they co-occur in our sample of texts and the line weights show the relative frequency of co-occurrence.

Sociotechnical Configurations

The preceding analysis took a deep dive into the components that make up urban carbon neutral imaginaries by examining the sociotechnical objects and instruments featured in climate governance policy documents. We identified which sociotechnical objects to include in the concept maps through the discourse analysis. In each city's policy documents, however, sociotechnical objects are assembled together in particular configurations. In addition to feeding into the textual network analysis, the discourse analysis allowed us to interpret three key sociotechnical configurations of urban carbon neutrality (see Table 3). Recall that these configurations are not explicitly given within the texts. Instead, they are heuristic constructs that allow us to interpret the ways that sociotechnical objects are being drawn together in the texts to tell a story about what a future carbon neutral city might look like in a particular place. In our analysis, the relations that bind discourses, material objects and policy instruments are co-constitutive—their meaning and significance for decarbonization is to be understood through the relations that compose the configurations. In practice, these imagined

configurations exist in overlapping fashions in the policy documents for particular cities. Here, they are distinguished for analytical purposes in order to highlight which sociotechnical configurations are being normatively privileged. When considering these heuristic configurations, recall that this study focused on buildings and energy and excluded transportation to maintain a manageable scope.

Table 3 Heuristic types of urban building and energy configurations interpreted from the climate governance document sample

The District Energy City: An efficient and compact built environment powered by biomass CHP This carbon neutral city of the future is characterized by a dense built environment and compact urban development as the city continues to expand. The use of resources is highly efficient due to modern technology upgrades to buildings, with a particular focus on energy efficiency. Heat is provided to buildings through a district energy system that is highly interconnected. Extensive heat network infrastructure is embedded into the fabric of the city. Energy production focuses on combined heat and power systems fuelled largely by biomass.
The Zero Net Energy City: Efficient buildings powered by building integrated PV and distant wind power This carbon neutral city of the future is typified by technologically advanced buildings that produce as much energy as they use. Buildings are energy efficient and solar photovoltaics are integrated into the built form of the city. The behaviour of individuals is one focus of governance. Further renewable energy is supplied by wind turbines located physically distant from the core urban area.
The Natural Gas Transition City: District energy powered by natural gas with a renewable gas future This carbon neutral city of the future passes through a phase of development focused on natural gas expansion in order to transition the energy system from coal. Extensive district energy infrastructure connects and supplies heat to many buildings in the city. CHP plants fuel the district energy system in the near term. At an indeterminate point in the future, natural gas will be replaced as a fuel, perhaps through the incorporation of renewable gas.

We have not categorized the studied cities because, in practice, urban actors are taking multifaceted approaches to achieve carbon neutrality and we wish to avoid essentializing the approach taken in each city. However, we include the following examples to offer deeper insight and bring alive the narratives of carbon neutrality taking shape among the members of the Carbon Neutral Cities Alliance. In Stockholm, one expression of the carbon neutral imaginary is similar to the District Energy City

configuration. District energy has been a central urban infrastructure for many years. Continued fuel switching to biomass and waste-to-energy technology as well as district energy infrastructure expansion will continue this pattern to achieve decarbonization. This configuration is pursued in combination with a compact and very energy efficient built environment (City of Stockholm, 2014). In San Francisco, low carbon urbanism will continue to emphasize solar PV generation. Zero net energy approaches to building development and retrofit are key to low carbon plans in San Francisco, which combines energy efficiency and on-site renewable generation (City of San Francisco, 2013). In London, the planned carbon neutral future includes a role for natural gas expansion to power district energy generation. This natural gas expansion is positioned as a bridge between existing coal-fired power plants and future lower or zero carbon energy sources that would be substituted into the district energy generation system. Potential fuel sources for future substitution are waste heat or biogases that not yet considered commercially viable options (Mayor of London, 2011). Of course, other options are being pursued in all three places and the complicated work of decarbonization cannot be adequately summed up in three standard configurations. Nonetheless, the application of our three heuristic configurations makes it clear that an emphasis on different sociotechnical configurations drives different material interpretations of carbon neutrality.

Discussion

The empirical analysis broke down planning approaches to decarbonization into constitutive sociotechnical elements. It showed that the emphasis within the studied policy documents rests particularly on district energy, energy efficient technology, and solar power, but that future carbon neutral cities are broadly imagined as complex configurations. The policies that will be used to achieve carbon neutrality include both regulatory and voluntary policy instruments, although the emphasis on the latter may reflect limited regulatory power over relevant sectors as well as a desire to enlist private capital as a partner. In sum, a key finding is that efforts to achieve urban carbon neutrality will be manifold; instead of a silver bullet, cities plan to use a multi-pronged approach. This diversity reflects the experimental nature of urban carbon governance (Castán Broto & Bulkeley, 2013; Hoffmann, 2011). Experimental climate governance produces knowledge through trial and error involving a range of urban elements and depends on processes of reflexivity, revision and learning (Kivimaa, Hildén, Huitema, Jordan, & Newig, 2017; Sabel & Zeitlin, 2011). The diversity could reflect urban actors' efforts to trial new approaches and test out ideas in the pursuit of decarbonization.

Despite this overall diversity, our discourse analysis identified that carbon neutral governance is coalescing in particular places around configurations that emphasize some sociotechnical objects over others. This suggests that the socio-material nature of

different cities influences their imagined path towards carbon neutrality. Sociotechnical imaginaries constituted from these divergent configurations will embed different understandings into society about how a carbon neutral urban life ought to be lived. By comparing three of the evolving configurations of planned carbon neutral cities, the findings show how an emphasis on a different sociotechnical configuration drives different material interpretations of carbon neutrality. If a sociotechnical imaginary based on the District Energy City configuration were to take hold, for example, it would drive policy and investments to enable the development of networked infrastructure to conduct heat and electricity between interconnected buildings and motivate dense urban planning for urban expansion. Biomass, natural gas, and waste to energy fuel sources would likely be emphasized since they fit with the district energy design. If, instead, an imaginary emphasizing the Zero Net Energy City configuration was adopted, it would drive policy and investment in energy efficient and renewably powered individual buildings. Aspects of density and connection are likely to be less important in this imaginary, which could lead to very different building and neighbourhood design. The sun and wind might be emphasized as energy sources and the behaviour of individuals within buildings may be seen as a key issue. Each of these sociotechnical imaginaries of urban carbon neutrality enables some futures and not others, which has significant spatial ramifications for future urban development and the politics of contestation over who will benefit or lose from which future is achieved.

This study focused on imaginaries of the future, but these imaginaries are, of course, influenced by existing configurations and conditions. Historical development patterns have created cities that already have extensive district heating infrastructure – for example, Stockholm and some other European cities – or created cities connected to coal dependent regional electricity grids – for example, London. Social, economic, technical and political conditions shape the possibilities imagined for the future; different kinds of cities generate different imaginaries. Furthermore, this study is based on climate governance documents that describe the future, but they are not passive policy documents outlining a potential path. Instead, the imaginaries represented through these documents are prescribing attainable and desirable futures and delimiting the nature of carbon neutrality. This has real impact on policy outcomes. Imaginaries are repeatedly embedded into infrastructure and institutions as policies are enacted, thereby guiding urban futures through their repeated performance. This feedback between talk and practice makes it clear how the language studied in this paper does political work to pave the way for different kinds of cities. Yet, a limitation of a sociotechnical configurations approach to understanding imaginaries of the future is that it does not, by itself, address power dynamics. Our results suggest that in the interstices of sociotechnical configurations are differences in place histories and trajectories that critical discourse analysis can help make perceptible and appreciable.

Finally, the climate governance documents studied in this paper are transnationally connected through affiliated actors' participation in the Carbon Neutral Cities Alliance. Despite the shared terminology of 'carbon neutral', the findings show that there is some diversity in what carbon neutral materially means in different cities. While divergence could be an effective way of respecting different local circumstances (e.g. no accessible biomass source or good conditions for solar photovoltaics), the dominance of particular configurations could also potentially limit the scope of urban carbon neutral imaginaries. Widespread integration of the Natural Gas Transition City configuration into imaginaries, for instance, will create new interests in fossil fuels that will be difficult to overcome. It is often represented as a simple technological substitute to make the switch to renewable gas fuel, but the entrenchment of fossil fuels is stubbornly political (Bernstein & Hoffmann, 2018). The ambiguous use of 'carbon neutral' sometimes obscures our understanding of what kinds of ideas about sociotechnical objects and relations are becoming powerful and makes it difficult to see that very different configurations are being institutionalized – including configurations that perpetuate fossil fuel dependence. In other words, diversity under the umbrella of carbon neutrality can conceal the continuation of the status quo in terms of the perpetuation of fossil fuel entrenchment. Nonetheless, the idea of carbon neutrality is acting as a policy umbrella for urban actors interested in pursuing deep decarbonization. Under this umbrella, sharing and learning is taking place among the members of the Carbon Neutral Cities Alliance. Carbon neutral discourses are materializing multi-scalar assemblages through urban governance networks that offer opportunities to push the boundaries of urban carbon governance practice.

Conclusion

The urban carbon governance efforts of the members of the Carbon Neutral Cities Alliance (CNCA) are shaping what it means to be a carbon neutral city. Transnational governance networks such as the CNCA are entangled with visions of scientific and technological progress that influence understandings of collective futures and public good, but these sociotechnical imaginaries vary across localities. 'Carbon neutrality' is a mutable idea, which makes it unclear what kinds of future urban systems are imagined. In this paper, we have unpacked urban imaginaries of carbon neutrality represented in the policy documents of the founding members of the Carbon Neutral Cities Alliance to examine the constitutive sociotechnical configurations.

We found that decarbonization planning documents emphasize district energy, energy efficient technology, and solar power while leaving other sociotechnical objects out and

that, overall, urban deep decarbonization pioneers are planning to use a complicated suite of objects and policies to reach their goals. Clearly, given the complexity of sociotechnical objects mobilized among the CNCA members, these paths offer a means to steer governance towards achieving decarbonization. Yet, as our textual discourse analysis suggests, while the dominant configurations offer pathways, other urban actors pursuing carbon neutrality will necessarily have to meander through diverse trajectories to attain their goal. In addition, it important to note that the group of cities studied here is not even close to a comprehensive representation of global diversity. Care should be taken to avoid inappropriate prescription based on these findings that eschews demands for North-South redistributive justice in climate change mitigation governance.

The scope of planned urban change described in this paper is more ambitious than the scope of action that has been found in previous studies. Few European cities plan to be climate, energy or carbon neutral (Reckien et al., 2014) and urban climate governance has largely been incremental without targeting key drivers of greenhouse gas emissions and systemic change (Bulkeley & Betsill, 2013; Romero-Lankao, 2012). Carbon neutral cities, according to the studied documents, will be systematically powered and built differently, and individuals within cities will socially relate to one another in new ways. These efforts to picture and plan for carbon neutral urban futures are important interventions in a policy space that has been preoccupied with incremental emission reductions. With these efforts, urban actors are drawing together various urban elements to create a story about what a carbon neutral city could look like in a particular place. These stories are powerful because they shape our understanding of the future, which is then incorporated into the on-going construction, demolition and maintenance of urban systems. As other research has shown, stories are an engaging way to imagine energy futures (Smith et al., 2017).

However, this paper also brings some concerns to light. The findings uncovered few signs in the policy documents that the transition to carbon neutrality will require confrontation. For example, the documents largely emphasize ‘carrot’ over the ‘stick’ approaches to policy design. While this finding may be influenced by the limitations of local government powers, it also contributes to a depoliticization of carbon neutral governance. Others have called for increased recognition of the necessary role of contestation in climate governance (Kenis & Lievens, 2017; Swyngedouw, 2010). Disagreements can be fundamental, including contestation about both the goals (‘What does carbon neutral look like for this city?’) and the means (‘What kind of social and economic re-ordering is required?’) of climate governance. We have unpacked what it means to strive for carbon neutrality at a time when urban actors are just starting to experiment with governance in this area in order to facilitate a broader conversation about the evolving pathways of carbon neutrality and the winners and losers of urban

transformation. The sociotechnical imaginaries of the future we describe sensitize previous research on the governance of energy transitions to the histories, stories and trajectories of different cities, yet there is a need to hone skills for being attuned and responsive to how tensions are provoked and subsumed within sociotechnical configurations.

Future research can build on the work done here to unsettle the meaning of urban carbon neutrality in order to explore contestation in carbon governance. It is also essential that future research examines the material implementation of urban carbon neutral governance beyond the textual approach taken for this paper. The negotiation of decarbonization is ongoing and experimental, but the development of powerful sociotechnical imaginaries, as well as their investment in institutions and infrastructure, already shapes nascent decarbonization pathways.

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References

Anderson, B. (2006). *Imagined communities: reflections on the origin and spread of nationalism*. New York: Verso.

Angelo, H., & Wachsmuth, D. (2014). Urbanizing Urban Political Ecology: A Critique of Methodological Cityism. *International Journal of Urban and Regional Research*, n/a-n/a. https://doi.org/10.1111/1468-2427.12105

Bernstein, S., & Hoffmann, M. (2018). The politics of decarbonization and the catalytic

impact of subnational climate experiments. *Policy Sciences*. https://doi.org/10.1007/s11077-018-9314-8

Bijker, W. E., & Law, J. (1992). *Shaping technology / building society: studies in sociotechnical change.* Cambridge, MA: MIT Press.

Borgatti, S., Everett, M., & Freeman, L. (2002). *UCINET for Windows: software for social network analysis*. Harvard, MA: Analytic Technologies.

Boyko, C. T., Gaterell, M. R., Barber, A. R. G. G., Brown, J., Bryson, J. R., Butler, D., … Rogers, C. D. F. F. (2012). Benchmarking sustainability in cities: The role of indicators and future scenarios. *Global Environmental Change*, *22*(1), 245–254. https://doi.org/10.1016/j.gloenvcha.2011.10.004

Bulkeley, H., & Betsill, M. M. (2013). Revisiting the urban politics of climate change. *Environmental Politics*, *22*(1), 136–154.

Bulkeley, H., & Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers*, *38*(38), 361–375. https://doi.org/10.1111/j.1475-5661.2012.00535.x

Burch, S. (2010). In pursuit of resilient, low carbon communities: An examination of barriers to action in three Canadian cities. *Energy Policy*, *38*(12), 7575–7585. https://doi.org/10.1016/j.enpol.2009.06.070

C40 Cities, & ARUP. (2014). *Climate Action in Megacities 2.0*.

Carbon Neutral Cities Alliance. (2015). *Framework for Long-Term Deep Carbon Reduction Planning*.

Carley, K. M. (1993). Coding choices for textual analysis: a comparison of content analysis and map analysis. *Sociological Methodology*, *23*, 75–126.

Castán Broto, V., & Bulkeley, H. (2013). A survey of urban climate change experiments in 100 cities. *Global Environmental Change*, *23*(1), 92–102. https://doi.org/10.1016/j.gloenvcha.2012.07.005

Çinar, A., & Bender, T. (2007). *Urban imaginaries: locating the modern city*. Minneapolis: University of Minnesota Press.

City of San Francisco. (2013). *Climate Action Strategy 2013 Update*. San Francisco: City of San Francisco. Retrieved from https://sfenvironment.org/sites/default/files/engagement_files/sfe_cc_ClimateActionStrategyUpdate2013.pdf

City of Stockholm. (2014). *Roadmap for a fossil fuel-free Stockholm 2050*. Retrieved from http://www.stockholm.se/PageFiles/463655/Roadmap for a fossil fuel-free Stockholm 2050.pdf

Coutard, O. (1999). *The governance of large technical systems*. New York, NY: Routledge.

Foucault, M. (1972). *The archeology of knowledge*. New York: Vintage Books.

Gandy, M. (2004). Rethinking urban metabolism: water, space and the modern city. *City*, *8*(3), 363–379. Retrieved from

http://www.tandfonline.com/doi/abs/10.1080/1360481042000313509
Garb, Y., Pulver, S., & Vandeveer, S. D. (2008). Scenarios in society, society in scenarios: toward a social scientific analysis of storyline-driven environmental modeling. *Environmental Research Letters*, *3*(4), 45015–45018.
Genus, a., & Theobald, K. (2016). Creating low-carbon neighbourhoods: a critical discourse analysis. *European Urban and Regional Studies*, *23*(4), 1–16. https://doi.org/10.1177/0969776414546243
Goodwin, B., & Taylor, K. (2009). *The Politics of Utopia: A Study in Theory and Practice*. New York, NY: Ralahine Classics.
Hajer, M., & Versteeg, W. (2005). A Decade of Discourse Analysis of Environmental Politics : Achievements , Challenges , Perspectives. *Journal of Environmental Policy & Planning*, *31*, 175–184.
Hoffmann, M. (2011). *Climate governance at the crossroads*. Oxford: Oxford University Press.
Huber, M. (2015). Theorizing Energy Geographies. *Geography Compass*, *9*(6), 327–338. Retrieved from http://doi.wiley.com/10.1111/gec3.12214
Hult, A. (2013). Swedish Production of Sustainable Urban Imaginaries in China. *Journal of Urban Technology*, *20*(1), 77–94.
Jasanoff, S., & Kim, S.-H. (2009). Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva*, *47*(2), 119–146. https://doi.org/10.1007/s11024-009-9124-4
Jasanoff, S., & Kim, S.-H. (2015). *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago: The University of Chicago Press.
Kenis, A., & Lievens, M. (2017). Imagining the carbon neutral city: The (post)politics of time and space. *Environment and Planning A*, *49*(8), 1762–1778. https://doi.org/10.1177/0308518X16680617
Kivimaa, P., Hildén, M., Huitema, D., Jordan, A., & Newig, J. (2017). Experiments in climate governance – A systematic review of research on energy and built environment transitions. *Journal of Cleaner Production*, *169*, 17–29. https://doi.org/10.1016/j.jclepro.2017.01.027
Marres, N. (2012). *Material participation: Technology, the environment and everyday politics*. New York, NY: Palgrave Macmillan.
Mayor of London. (2011). *Delivering London's Energy Future*. Retrieved from https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Energy-future-oct11.pdf
Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences*, *42*(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z
Palmquist, M. E., Carley, K. M., & Dale, T. A. (1997). Applications of computer-aided

text-analysis: analyzing literary and nonliterary texts. In C. W. Roberts (Ed.), *Text Analysis for the Social Sciences*. Mahwah, NJ: Lawrence Erlbaum Associates.

Reckien, D., Flacke, J., Dawson, R. J., Heidrich, O., Olazabal, M., Foley, A., … Pietrapertosa, F. (2014). Climate change response in Europe: What's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. *Climatic Change*, *122*(1–2), 331–340. https://doi.org/10.1007/s10584-013-0989-8

Romero-Lankao, P. (2012). Governing Carbon and Climate in the Cities: An Overview of Policy and Planning Challenges and Options. *European Planning Studies*, *20*(1), 7–26.

Sabel, C. F., & Zeitlin, J. (2011). Experimentalist governance. In D. Levi-Faur (Ed.), *The Oxford handbook of governance*. Oxford: Oxford University Press.

Scott, J. (1991). *Social network analysis: A handbook*. Newbury Park, CA: SAGE Publications.

Shaw, A., Sheppard, S., Burch, S., Flanders, D., Wiek, A., Carmichael, J., … Cohen, S. (2009). Making local futures tangible—Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. *Global Environmental Change*, *19*(4), 447–463.

Smith, J., Butler, R., Day, R. J., Goodbody, A. H., Llewellyn, D. H., Rohse, M. H., … Whyte, N. M. (2017). Gathering around stories: Interdisciplinary experiments in support of energy system transitions. *Energy Research and Social Science*, *31*, 284–294. https://doi.org/10.1016/j.erss.2017.06.026

Swyngedouw, E. (2010). Apocalypse forever?: Post-political populism and the spectre of climate change. *Theory, Culture and Society*, *27*(2), 213–232. https://doi.org/10.1177/0263276409358728

Taylor, C. (2004). *Modern social imaginaries*. Durham: Duke University Press.

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy*, *28*(12), 817–830.

USDN. (2015, January 1). Carbon Neutral Cities Alliance. *Urban Sustainability Directors Network Website*. Retrieved from https://www.usdn.org/public/page/13/CNCA

Waitt, G. (2005). Doing discourse analysis. In I. Hay (Ed.), *Qualitative research methods in human geography*. Oxford: Oxford University Press.

Walker, G., & Cass, N. (2007). Carbon reduction, "the public" and renewable energy: engaging with socio-technical configurations. *Area*, 458–469.